DEPARTMENT OF THE NAVY
BUREAU OF MEDICINE AND SURGERY
WASHINGTON, D.C. 20390

IN REPLY REFER TO
NAVMED P-5055 CH-3
BUMED-742
6 November 1968

NAVMED P-5055 CHANGE TRANSMITTAL

From: Chief, Bureau of Medicine and Surgery
To: All Ships and Stations

Subj: CH-3 to NAVMED P-5055, subj: Radiation Health Protection Manual

Encl: (1) Revised pages to subject instruction

1. Purpose.

a. To issue revised procedures for reporting of medical or dental therapeutic radiation exposures obtained from physical examinations and medical histories.

b. To issue revised processing techniques and film calibration curves for the Kodak Type 3 Personnel Beta/Gamma Monitoring Film. An accident dosimeter interpretation procedures and revised administrative requirements are also incorporated in this revision.

2. Action. Insert the enclosed pages in their proper place in the subject manual; remove the old pages; and enter the change in the record of changes. These changes are effective immediately.

3. Availability. The NAVMED P-5055 and additional copies of changes 1, 2, and 3 to the NAVMED P-5055 are stocked for issue through the Forms and Publications segment of the Navy Supply System and may be procured from appropriate cognizant "I" supply distribution points in accordance with NAVSUP P-2002.

R. B. BROWN

LIST OF TABLES

Chapter 2

MEDICAL EXAMINATIONS

2–1. Preplacement Medical Examinations

(1) *Personnel Involved.*—All personnel who are being considered for routine assignment to duties or occupations requiring exposure to ionizing radiation or the handling of radioactive materials shall be given a medical examination prior to assignment or transfer to those duties or occupations. Personnel who are not routinely exposed to ionizing radiation during their normal occupation are not required to have pre-radiation exposure medical examinations provided they are not likely to exceed 500 mrem per year or 300 mrem per quarter.

(2) *Scope.*—The preplacement examination shall include, but not be limited to, a careful history, complete and thorough physical examination, chest X-ray, baseline blood study, and other clinical laboratory studies and bioassays as indicated. If a physical examination has been conducted within the past 6 months, it may be accepted in whole or in part, at the discretion of the cognizant medical officer, in lieu of the corresponding sections of the preplacement examination, provided a record of such examination is available in the individual's Health Record (military), or Industrial Health Jacket (civilian).

(a) *Medical History.* A complete medical history shall be obtained in accordance with the appropriate sections of MANMED chapter 15 or FedPerMan chapter 339. In addition to the medical history requirements of MANMED chapter 15 or FedPerMan chapter 339, the following histories on naval personnel and civilian employees who have received medical or dental therapeutic radiation shall be submitted to Code 74, Bureau of Medicine and Surgery for evaluation by a Medical Advisory Board:

1. Industrial history to determine the amount of ionizing radiation previously received as the result of occupational exposure.

2. Past medical history to evaluate any previous malignancies and blood dyscrasias.

3. A history of medical or dental therapeutic radiation estimating the amount of ionizing radiation previously received for medical or dental therapy shall be elicited and appropriately recorded.

4. Family history to elicit the presence of malignancies, blood dyscrasias, congenital defects, sterility, cataracts, etc., in parents, siblings, and collateral lines.

(b) *Physical Examination.* A complete and thorough physical examination shall be conducted in accordance with MANMED chapter 15 or FedPerMan chapter 339, as applicable. Careful inspection shall be accomplished to elicit evidence of precancerous and cancerous skin lesions, lymphoma, Hodgkin's disease, blood dyscrasias, lenticular opacities, etc., which might also be produced or aggravated by exposure to ionizing radiation. Special attention shall be accorded to the following:

1. Eye Examinations. The medical examiner shall perform an ophthalmoscopic examination on all personnel. A careful inspection shall be made to establish the presence of any corneal nebulas, maculas, or leucomas, chronic corneal ulcers, chronic or recurrent keratitis, lenticular opacities, etc., which might be misinterpreted on a subsequent medical examination as lesions resulting from exposure to ionizing radiation.

2. Slit Lamp Examinations. Slit lamp examinations shall be conducted on all personnel who have received or are likely to receive a dose of ionizing radiation in excess of 5 rem, or a dose of neutrons in excess of 1 rem, during the subsequent year or who are assigned duties within the radiation areas of particle accelerators, or experimental or research reactors; and on all others deemed necessary by the cognizant medical officer. Slit lamp examinations shall be conducted by an ophthalmologist, optometrist, or medical officer experienced in the use of the slit lamp. When adequate slit lamp examinations cannot be accomplished within the local command, these examinations shall be completed in accordance with the instructions contained in article 3–1 of this manual.

(c) *Laboratory Procedures.* Laboratory tests shall include, as indicated:

1. Chest X-ray. To reduce medical exposure to ionizing radiation, a 14 x 17 inch chest X-ray should be taken on all personnel as part of the preplacement medical examination, rather than a 70 mm photofluorogram.

2. Blood Study. A baseline blood study consisting of a hemoglobin determination, total white cell and differential count and a hematocrit determination shall be made. Table I lists the "normal" values for these blood constituents. Since universal agreement on normal values is lacking, this table is presented as a guide.

TABLE I
NORMAL BLOOD CONSTITUENTS

Blood constituents	Male	Female
Hemoglobin	13–18 gms	12–17 gms
Hematocrit	40–54	37–47
Leukocytes	4,000–12,000	4,000–12,000
Neutrophiles	55–80%	55–80%
Lymphocytes	20–45%	20–45%
Bands and juveniles	0–10%	0–10%

3. Urinalysis. A routine urinalysis shall be performed on all individuals. When deemed necessary by the cognizant medical officers, a radiochemical urinalysis shall be performed on personnel who have previously engaged in handling radioactive material not hermetically sealed. When radiochemical urinalysis cannot be accomplished within the local command, urine samples shall be collected and shipped to the appropriate medical support facility in accordance with the instructions contained in article 3–2 of this manual.

4. Radon Breath Sample. Breath samples to determine the concentration of radon in expired air shall be obtained from all personnel who have been or will be engaged in handling radium (or its compounds) which is not hermetically sealed. These breath samples shall be collected and shipped to the medical support facility in accordance with the instructions contained in article 3–3 of this manual.

5. Bioassays. In addition to radio chemical urinalysis and breath measurements for radon activity, whole body radiation counts, body scanning with a scintillation counter and other bioassay techniques for the determination of radioactivity in body tissues, secretions, and excretions can be performed as required by competent medical authority. When deemed necessary by the cognizant medical officer of a ship, unit, or command which lacks the capability to perform body counts, scanning, or bioassays, a request should be submitted by that ship, unit, or command to the nearest designated support facility for approval and assistance in obtaining these tests in accordance with the instructions in article 3–4 of this manual. Internal contamination should be assessed by whole body counting or scanning techniques.

(3) *Medical Requirements.*—The general medical requirements include those which are required for active duty in the military service or for civil service employment as defined in MANMED and FedPerMan, respectively. In addition to failure to meet the general medical requirements, the following are considered disqualifying:

(a) *Medical History.* Any history of occupational radiation exposure in excess of that allowed by paragraph 4–3 of this instruction or the instruction applicable at the time of exposure, or any evidence of previous radiation injury which is considered disqualifying by the medical examiner shall be evaluated by Code 74, Bureau of Medicine and Surgery.

(b) *Physical Findings.* The presence of any physical condition such as precancerous and cancerous skin lesions, chronic corneal ulcers, cataracts, bleeding tendencies, or any other condition which might, in the opinion of the cognizant medical officer, be aggravated by occupational exposure to ionizing radiation, shall be disqualifying. An individual who has an open wound (whether laceration, abrasion or ulceration) is disqualified from handling radioactive materials which are not hermetically sealed unless the wound is adequately protected from radioactive contamination or until such time as the medical examiner considers that the wound is sufficiently healed.

(c) *Laboratory Procedures.* From the results of the laboratory tests, the decision to disqualify an individual shall be based on the following considerations:

1. Hematology. Any deviation from the normal hematological values enumerated in table I shall be evaluated by the cognizant medical officer. In cases where abnormalities may be due to transient disease or other temporary conditions, the individual may be temporarily disqualified by the medical officer. A reexamination shall be made after the individual has recovered from the illness. No one shall be qualified for exposure to radiation when, in the opinion of the cognizant medical officer, a gross hematological abnormality exists.

2. Bioassays. The presence of plutonium, uranium, radioactive rare earths or other biologically long-lived isotopes in the urine or other bioassay material shall be carefully evaluated by the medical officer. Whole body counting techniques should be utilized to detect internal fission fragment contamination. If it is likely that the individual has in excess of 100 percent of his maximum permissible body burden for any of these radioactive materials, as defined in National Bureau of Standards Handbook 69, he shall be disqualified from performing duties in a radiation area. If it is determined that

the individual has a measurable body burden greater than 10 percent or less than 100 percent of the maximum permissible body burden, he may be permitted to perform duties in a radiation area when approved by the Bureau of Medicine and Surgery, Code 74.

3. Breath. The presence of more than 5 x 10^{-13} curies of radon per liter of expired air is disqualifying.

(4) *Records.*—The results of the preplacement examination shall be recorded on NAVMED 6150/2 for military personnel, or the industrial jacket for civilian personnel.

(a) *Physical Examination.* In addition to all other physical findings, the following information shall be recorded:

1. Eye Examinations. All abnormalities noted in the ophthalmoscopic examination shall be described in detail and recorded diagrammatically on Standard Form 600 (Chronological Record of Medical Care), which is to be clearly marked: "TO BE RETAINED PERMANENTLY IN HEALTH RECORD."

2. Slit Lamp Examination. The results of the slit lamp examination shall be recorded on a Standard Form 600, which is to be clearly marked: "TO BE RETAINED PERMANENTLY IN HEALTH RECORD." All abnormalities shall be described in detail and recorded diagrammatically.

(b) *Laboratory Procedures.* The results of the laboratory tests shall be recorded as follows:

1. Blood Study. The results of the baseline blood study shall be recorded on a Standard Form 600, which is to be clearly marked: "TO BE RETAINED PERMANENTLY IN HEALTH RECORD." This Standard Form 600 shall be reserved for the results of this and all subsequent blood studies obtained on radiation physical examinations.

2. Bioassays. The results of all radiochemical urinalysis, radon breath samples, whole body counts, and other bioassays shall be recorded on a Standard Form 600, which is to be clearly marked: "TO BE RETAINED PERMANENTLY IN HEALTH RECORD."

2–2. Periodic Reexaminations

(1) *Frequency.*—All personnel who perform their normal duties or occupations in a radiation area, or who occasionally enter a high radiation area in the normal course of their duties or occupations shall be given an annual medical examination, except that all such personnel who have received less than 5 rem during the previous calendar year may be exempted from this examination at the discretion of the cognizant medical officer.

(2) *Scope.*—The periodic reexamination may be used in conjunction with, or as part of an annual, promotion, reenlistment, retirement, or other physical examination. That portion of any physical examination required for the periodic reexamination of a radiation worker shall include, but not be limited to, an interval history, physical examination and blood count. A history of receiving medical or dental therapeutic radiation while employed as an industrial radiation worker shall be submitted to Code 74, Bureau of Medicine and Surgery for evaluation by a Medical Advisory Board in accordance with the requirements of paragraph 2–1. Medical officers shall assure that therapeutic radiation exposures are brought promptly to their attention without waiting for the next annual physical exam.

(a) *Medical History.* The medical history may be limited to that interval of time since the last radiation physical examination. Examiners should be alert for symptoms of chronic radiation illness such as fatigue, malaise, anorexia, and anxiety regarding exposure to radiation.

(b) *Physical Examination.* The physical examination shall include a careful inspection to detect the presence of weight loss; corneal or lenticular opacities; dryness, cracking, atrophy, depigmentation, ulceration, precancerous or cancerous lesions of the skin, especially of the hands and face; excessive longitudinal corrugation and brittleness of the fingernails; and any other signs of injury which could arise from exposure to ionizing radiation.

(c) *Laboratory Procedures.* Laboratory tests shall include:

1. Hematology. The blood count shall consist of a total white cell and differential count, and a hematocrit and hemoglobin determination. Any deviation from the individual's baseline blood study shall be evaluated by the cognizant medical officer.

2. Exceptions. Slit lamp examinations, chest X-rays, routine urinalysis, radiochemical urinalysis, breath samples, and other bioassays are not considered an essential part of a routine reexamination for radiation exposure, but may be included at the discretion of the medical officer. If conducted, slit lamp examinations, radiochemical urinalysis and radon breath samples shall be performed in accordance with article 2–1 (2) (b) of this manual. When a periodic chest X-ray is required, a 14 x 17 inch chest film should be used rather than a 70 mm photofluorogram.

(3) *Physical Requirements.*—The general physical requirements are those for continuation on active duty in the military service or in civil service employment as defined in MANMED or FedPerMan, as appropriate. In addition to failure to meet the general physical requirements for retention in the military service or for civil service employment, any evidence which, in the opinion of the cognizant medical officer, is indicative of radiation injury, shall be considered disqualifying. Any deviation in the results of the laboratory tests which do not con-

form with the limits as defined in article 2–1 (3) shall be considered disqualifying.

(4) *Records.*—The results of the periodic radiation examinations shall be recorded on Standard Form 600 and NAVMED 6150/2 in the individual's Health Record, or the Industrial Health Jacket, in accordance with paragraph 2–1 (4) of this manual.

2–3. Special Examinations

(1) *Slit Lamp Examinations.*—Slit lamp examinations shall be performed annually on all personnel who have received in excess of 5 rem of ionizing radiation (total beta, gamma, and neutron), or in excess of 1 rem of neutron radiation during the preceding year, or as deemed necessary by the cognizant medical officer. The results of slit lamp examinations shall be recorded in detail and diagrammatically on Standard Form 600, which is to be clearly marked: "TO BE RETAINED PERMANENTLY IN HEALTH RECORD."

(2) *Bioassays.*—When deemed necessary by the cognizant medical officer, a radiochemical urinalysis or other indicated bioassay shall be performed every 6 months on all personnel engaged in handling plutonium, uranium, radioactive rare earths, or other long-lived radioisotopes, and on personnel having in excess of 25 percent of the maximum body burden for any of these radioactive substances. The results of these bioassays shall be recorded on a Standard Form 600, which is to be clearly marked: "TO BE RETAINED PERMANENTLY IN HEALTH RECORD."

(a) *Internal Contamination.* Results of all internal contamination measurements shall be recorded in the remarks section of the individual's DD 1141, Record of Exposure to Ionizing Radiation, and reported in the remarks section of the NAVMED 1432, Personnel Exposure to Ionizing Radiation, Report Symbol MED 6470–1. Activities that have electronic data processing capabilities and normally submit EAM type reports under Report Symbol MED 6470–3 will submit results of internal contamination in the "Remarks" section of NAVMED 1432, Report Symbol MED 6470–1.

(3) *Radon Breath Samples.*—Breath samples to determine the concentration of radon in expired air shall be obtained every 6 months from all personnel engaged in the handling of radium or its compounds which are not hermetically sealed. The results of these breath samples shall be recorded on a Standard Form 600, which is to be clearly marked: "TO BE RETAINED PERMANENTLY IN HEALTH RECORD."

(4) *Whole Body Counts.*—Whole body counting techniques should be utilized to detect internal fission fragment contamination. The results shall be recorded in the "Remarks" section of the individual's DD 1141 and in the "Remarks" section of the NAVMED 1432 when transferred or terminated.

2–4. Emergency Examinations

(1) *Frequency.*—An emergency medical examination shall be given to any individual who has received in excess of 25 rem of ionizing radiation in a single dose, or has possibly ingested or inhaled a significant amount of radioactive material, or as deemed necessary by the cognizant medical officer.

(2) *Scope.*—The emergency medical examination shall include an interval history, physical examination, and any special clinical and laboratory examinations as indicated. A report describing the circumstances of overexposure shall be submitted to BUMED, Code 74, in accordance with the requirements of article 5–3.

(3) *Action.*—The cognizant medical officer may hospitalize the individual for further evaluation or treatment, or return him to his normal occupation or duties, subject to the limitations and restrictions as defined in chapter 4 of this manual.

Chapter 6

PERSONNEL DOSIMETRY

6–1. Responsibilities

Personnel dosimetry is a technique for detecting and measuring an individual's exposure to ionizing radiation. The Bureau of Medicine and Surgery requires appropriate naval activities to maintain a dosimetry program for personnel who may be occupationally exposed to ionizing radiation. Personnel dosimetry is practiced in order to document an individual's exposure to determine if an overexposure has taken place and to aid in minimizing exposure. Personnel dosimetry has both medical and legal significance and must be conscientiously practiced by trained personnel under competent supervision.

(1) *Command Responsibility.*—The commanding officer of any activity where occupational radiation exposures are incurred shall insure that appropriate personnel dosimetric devices are supplied, and shall require the use of such devices (1) by all personnel who are likely to exceed 300 mrem per calendar quarter, (2) by all personnel entering a high radiation area, and (3) by all other personnel as deemed necessary. The type of dosimetric device or devices used shall be specified by the commanding officer, except that all radiographers and radiographers' assistants, as defined in Title 10, Part 34 of the Code of Federal Regulations, shall wear both a film badge and a self-reading dosimeter. Commanding officers shall be guided by applicable instructions stipulating the choice of dosimetric devices issued by various naval commands.

(2) *Individual Responsibility.*—When a personnel dosimetric device is required, it shall be worn at all times in any area where a radiation exposure may occur. The individual is responsible for loss of, or damage to such a device while in his possession. At the end of the working period, the dosimetric device shall be placed in a low-background area.

6–2. Dosimetric Devices

Acceptable dosimetric devices include: (1) film badges, (2) pocket dosimeters, (3) wrist badges and film rings, (4) luminescent dosimeters, and (5) accident dosimeters. Currently, film badges have the widest acceptance, and their use is emphasized in this chapter.

(1) *Film Badges.*—Film packets contain one or more photographic emulsions with varying degrees of sensitivity to beta particles, gamma rays, and X-rays, or to fast and thermal neutrons. Film packets are placed in the standard Navy stainless steel film badge holders, which are designed to differentiate between these radiations. Film badge holders are provided with a clip or other suitable means for attachment to the individual's clothing.

(a) *Normal Use.* The film badge shall be worn on the front surface of the head or trunk of the body, in the area expected to receive the highest exposure. When the location of maximum exposure to the body is not certain, additional dosimeters and/or film badges shall be worn. The film badge shall be worn on the outer garments, except where contamination of the badge could occur, or in difficult working conditions where the film badge might be lost. In such cases, the film badge should be worn under protective clothing. The wearer is responsible for his badge and the contained film and should take care to avoid its exposure to excessive heat, humidity, or moisture. Writing on any portion of the film other than the numbered portion should be avoided due to the pressure sensitive nature of the film emulsion.

(b) *Additional Use.* The film badge may be used as a means of identification for security purposes, provided the security program does not conflict with the photodosimetry program. Any alteration of the film badge must be approved by BUMED,

Code 74. Numbering or other identification may be placed on the steel strip between the open window and cadmium shield or on the clip.

(2) *Pocket Dosimeters.*—Pocket dosimeters are pencil-shaped ionization chambers calibrated to measure total exposure. They are available in ranges from 0–200 mrem to 0–600 rem.

(a) *Use.* Pocket dosimeters should be used in addition to film badges when higher levels of radiation may be encountered or when frequent exposure estimates are required. When used in addition to the film badge, the pocket dosimeter shall be worn in close proximity to the film badge. The choice of range and number of pocket dosimeters shall be made by the Radiation Control Officer.

(b) *Reliability Tests.* Pocket dosimeters must be tested for both drift and accuracy. These tests will be performed in accordance with NAVELEX, Standard Maintenance and Calibration Procedures for Dosimeters, Procedure number 3.A. Tests must be performed; (1) at least semi-annually unless otherwise specified by applicable instructions, (2) whenever new dosimeters are put into use, (3) whenever the dosimeter has been dropped or mishandled, and (4) whenever dosimeter readings appear to be in error by more than ± 15%.

(3) *Wrist Badges and Film Rings.*—For certain special situations, the wearing of wrist badges or film rings to measure radiation exposure to the forearms and hands may be required.

(4) *Luminescent Dosimeters.*—Other radiation detectors, which are not as commonly used, are referred to as luminescent dosimeters. This group includes both photoluminescent and thermoluminescent devices. The DT–60 ( ) ( )/PD*, which the Navy issues for NBC warfare defense purposes, is a silver phosphate photoluminescent type dosimeter. The DT–60 ( ) ( )/PD* will detect up to 600 rem of gamma radiation, other types of luminescent dosimeters may be used when approved by BUMED.

(5) *Accident Dosimeters.*—Accident dosimeters contain a number of neutron activation foils together with a high-range gamma thermoluminescent dosimeter. Most of these systems are capable of measuring neutron and gamma exposures up to and above 50,000 rem. Accident dosimeters are a supplement to the other dosimetric devices and can be built in or attached to a film badge. The purpose of accident dosimeters is to measure high exposures beyond the normal range of dosimetric film, such as might occur in a nuclear accident.

6–3. Photodosimetry Program

(1) *General Requirements.*—Photodosimetry is an evaluating technique which utilizes photographic emulsions sensitive to ionizing radiation to determine an individual's exposure. Radiation passing through a grain of silver halide in the emulsion causes a change, resulting in the conversion of the grain to atomic silver when the film is developed. The atomic silver causes a blackening of the emulsion which is measured as an increase in the optical density or as a darkened track of continuous granules. With proper calibration these changes can be related to radiation exposure.

(a) *Factors.* To obtain accurate results it is necessary to be consistent in all photodosimetric procedures. Among the many factors which affect film density are (1) emulsion type, (2) background density or base fog of the film, (3) type of film badge utilized, (4) type, concentration, age and temperature of the developing solution, (5) development time, (6) amount of agitation during development, (7) fixing time, (8) accuracy of the densitometer, and (9) operator error.

(b) *Density.* The above factors influence the density of film which has been exposed to radiation. To relate density to exposure, it is necessary to use a film calibration curve specifically developed for the type of film and radiation in question. Film calibration curves such as shown in Appendix C may be requested from BUMED, Code 7421. Other variables must be controlled as follows:

1. Control and exposed films must be from the same emulsion batch.

2. Control film is used to subtract base fog in order to obtain a net density for evaluation.

3. Control film shall be kept in an environment where temperature and humidity factors are similar to those where films are being worn or exposed. Control film must not be exposed to radiation above natural background levels.

4. Kodak Type 3 film is extremely sensitive to X and gamma radiation. Gamma radiation of 4 mrem produces a detectable increase in density. This film must not be stocked or stored near sources of radiation unless adequate shielding is provided.

5. All photographic film is subject to fogging by certain deterioration producing chemical vapors such as mercury, ammonia, or sulfur. Storage in areas where vapors may exist must be avoided, especially after the stock package has been opened and the vapor seal broken.

6. Unopened packages of stock film should be stored at 40 to 60 degrees F. Opened packages should be stored at room temperature (approximately 70 degree F.) at up to 50% relative humidity. If returned to cold storage, the vapor seal must be secured to prevent the forming of condensation when the cold film packets are again removed from the cold storage.

7. The variation of film response with photon energy complicates the proper evaluation of exposure to energies below 0.2 Mev. For X and gamma

* To remain blank, NAVELEX to issue new DT–60 model. Model number will be inserted in these spaces at a later date, upon issuance.

photons of 0.2 Mev to 3 Mev, the film response is essentially constant. Below this range the variable response may require special evaluation (energy correction curves), except in a limited range of diagnostic X-ray energies for which calibration curves are provided by BUMED, Code 7421 (see Appendix C).

8. Prior to issue of new film, one film from each package shall be processed to ensure that base fog of the fast component is within the normal range of approximately 0.3 density units for fresh film and not over 0.6 for film approaching its expiration date. Due to greater sensitivity, the initial base fog of Kodak Type 3 film will be greater than for Dupont Type 556.

9. Control film, check film, and exposed films must be processed together to eliminate the effects of processing variations.

10. Processing procedures must be standardized.

11. Processing solutions will not be used to exhaustion. A check film should be processed to be certain the base fog is within the normal range whenever developer solution is prepared.

(2) *Photodosimetry at Naval Activities.* — The Medical Department at each naval activity where military or civilian personnel are exposed to ionizing radiation shall maintain a Radiation Health Protection capability. A photodosimetry program is an essential part of this capability and its establishment shall be a responsibility of the senior medical representative present. Film processing, exposure evaluation, and exposure documentation are Medical Department functions to be supervised by the Radiation Health Officer or his assigned equivalent. The extent of the photodosimetry program at each activity shall be determined by BUMED (Code 74), based on the number of film badges utilized each month and the needs of each command. In all cases, the photodosimetry program will be adequate to meet the requirements of paragraph 6–1 (1).

(a) *Major Processing Activities.* Major processing activities are shipyards engaged in nuclear ship construction or upkeep; prominent Naval Research Laboratories utilizing radiation producing equipment or source materials; and, at BUMED option, Naval Hospitals utilizing diagnostic and therapeutic radiation equipment along with an extensive nuclear medicine program. Activities so designated shall include on their radiation protection staff persons well trained in all aspects of photodosimetry. They shall have processing equipment, measuring devices, and calibration sources appropriate to the execution of a complete high quality film monitoring program.

(b) *Special Processing Activities.* These activities have particular requirements determined by BUMED and include nuclear powered ships and nuclear powered ship tenders, submarine bases, and repair activities. Such commands may deal with high radiation intensities and may require immediate evaluations of personnel exposure. Therefore, trained technicians and/or supervisors along with processing and density measuring equipment are required and shall be provided to evaluate up to a few hundred dosimetric films per month. Film calibration curves and additional technical assistance will be provided these activities by BUMED (Code 7421).

(c) *Non-processing Activities.* Many naval facilities requiring a photodosimetry program will not be designated as either a major or special processing activity. Such activities utilize a comparatively small number of film badges per month and will have little need for on-the-spot exposure evaluations. These activities shall, nevertheless, maintain a Radiation Protection Program. The photodosimetry program must be adequate to provide the issuing of film badges and the recording and reporting of occupational exposures.

(d) *Film Processing Centers.* In the course of administering the Navy's Photodosimetry Program, BUMED has observed that cost reductions in equipment, manpower, and related training, as well as greater accuracy in exposure evaluation, can be achieved by keeping the number of major and special processing activities to a practical minimum. To this end, one or more Film Processing Centers will be maintained under BUMED management control. Such a center shall function to give film processing services to non-processing activities as well as to serve the Navy's photodosimetry program in aspects of research and technology. Requests for film processing services or other photodosimetry information may be made to BUMED, Code 7421. Currently, the Radiation Safety Department, National Naval Medical Center, Bethesda, Maryland 20014, is functioning as a film processing center.

(3) *Photographic Emulsions.*

(a) *Film Description.* Film Radiac Pack, FSN 6665–935–4327, Kodak Type 3, shall be used for detecting beta, gamma, and thermal neutron radiation. Type 3 film is available from the following distribution points: (1) NSB, New London; (2) NSC, Norfolk; (3) NSC, Charleston; (4) NSC, Oakland; (5) NSC, Long Beach; (6) NSC, San Diego; (7) NSC, Pearl Harbor.

Each film packet contains two component films: fast or "sensitive," and slow or "insensitive." In the film packet, the fast film is always in front of the slow film. The front of each packet is marked with a prefix letter followed by a 5 digit serial number for identification. This number appears on both films within the packet.

Kodak Personnel Neutron Monitoring Film, Type A, may be procured by open purchase, and

must be included in the film badge for personnel likely to receive neutron exposures. The neutron film is at present unnumbered; but will be provided a 5 digit serial identification number in the near future.

(b) *Sensitivity.* In general, film sensitivity varies with the type and energy of exposure. However, this occurs almost entirely at energies below 0.2 Mev. For example, an exposure 0.020 rem of hard gamma produces only 0.05 density units; while a similar exposure to lightly filtered 80 KVP diagnostic X-ray (approx. 30 Kev effective) results in a density of 1.2. Thus, the film is about 25 times more sensitive to low energy X-rays. The high sensitivity peak varies only slightly for lightly filtered X-ray energies in the range of 60 KVP to 120 KVP. Therefore, a standard calibration curve may be used for most exposures from diagnostic equipment. Correction factors for effective energies above and below this range are available from BUMED (Code 7421).

(c) *Film Range to Beta-Gamma.* For beta-gamma radiation the combined exposure range of the fast and slow Kodak Type 3 film is from 0.004 Rem to 150 Rem (density 3.0), 450 Rem (density 4.0), or 1000 Rem (density 4.6). For gamma exposure exceeding the range of Type 3 film, evaluations will be made from the thermoluminescent element of the accident dosimeter (range up to and above 50,000 Rem). NOTE: Accident dosimeters will be provided only in special cases, such as for personnel working around reactor fuel or operative reactor plants.

(d) *Film Range to X-ray.* Because of its high sensitivity to diagnostic X-rays, the combined exposure range of the fast and slow Type 3 film is from 0.001 Rem to 20.0 Rem (density 4.0, open window area). The range of the fast film for the open window area is limited to 0.080 Rem (density 4.0). To evaluate higher exposures on the fast film, density vs exposure curves are also plotted for metallic filter areas of different densities, i.e. Single Steel, Double Steel, and Cadmium. This family of curves serves two purposes: (1) They extend the range of the fast film to 10.0 Rem (Cd density 1.5); (2) They provide confirmation that the film exposure is in the energy range of the calibration curve. This is confirmed by observing the densities found in two or more filtered areas (or open window and one filter area) and should indicate approximately the same exposure when applied to the appropriate curve.

(4) *Film Badge Holders.*—The film packets are placed in film badge holders having various absorbers of different densities to differentiate between energies and type of ionizing radiations. The holder, Radiac Detecting Element FSN 6665–299–9825, is the standard item of issue and will be used in all cases unless prior approval is granted by BUMED, Code 74. This holder is constructed of stainless steel and provides five areas for density measurements: (1) "open window," (2) "closed window" or cadmium, (3) single steel, (4) double steel, and (5) cadmium plus single steel. Figure 1 illustrates

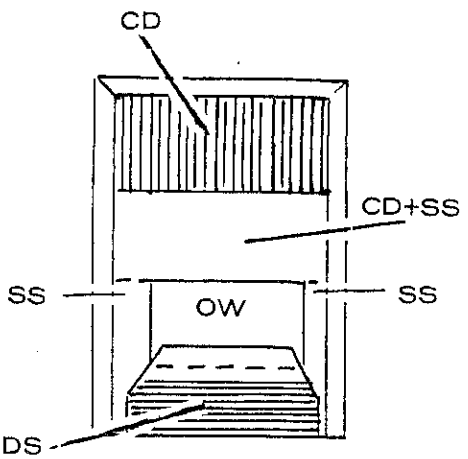


Fig. 1. Film Badge showing different areas where film densities may be measured.

the different areas of the badge. The holder comes equipped with a clip for fastening to an outer garment of the person being monitored. Any modification of this holder or adoption of a different film badge must have prior approval of BUMED, Code 74. As an exception, belt loops which enable the badge to be worn on the belt may be installed on the back side without prior approval. Type 3 film packets shall be placed in the film badge holders so that the letter designator preceding the serial number lies forward and at the open window end. If neutron film is used, it shall be placed behind the Type 3 packet with the opening tab to the rear and at the shielded end. If neutron film is not used, a "back-up" Type 3 packet must be placed behind the front film packet. This film should be given a distinctive mark and left in the badge for reuse. Back-up film is necessary in all cases where the exposure energy is above 0.660 Mev. It is important where the primary exposure is from Cobalt 60 (avg. energy 1.25 Mev). The Bureau of Medicine and Surgery gamma calibration curves are based on Cobalt 60. Without neutron or Type 3 "back-up" film, exposure to energies above 0.660 Mev will appear 15% to 20% high. This is a result of unattenuated back-scatter from the rear cadmium shield.

(5) *Densitometer.*—The densitometer is used to measure optical densities of dosimetric film. The density of the photographic emulsion, that is, the relative degree of darkening of the exposed and processed film, bears a definite relationship to the type of ionizing radiation and the amount of exposure.

(a) *Densitometers.* The MACBETH GN–304 model densitometer, FSN 6525–935–3640, has replaced the Weston Photographic Analyzer and the Photovolt Densitometer 501R and should be used exclusively as soon as available. The MACBETH densitometer includes a built-in density calibration filter which can be positioned in or out of the light path. This permits the operator to set the scale calibration by the flick of a lever, and eliminates the frequent use of the 21 step density calibration tablet furnished with the MACBETH densitometer. Densitometers other than the MACBETH are being phased out and are no longer under naval procurement. Nonstandard densitometers may continue to be used until the MACBETH GN–304 is available, provided they are properly calibrated with a standard density tablet. Kodak calibrated photographic step tablet number 3 with 21 steps ranging in density from approximately 0.02 to 3.9 should be obtained and used with nonstandard densitometers. Once a densitometer is properly zeroed and calibrated with the standard density tablet, it can be used with BUMED calibration curves. The calibration of a densitometer is verified by checking at least one density step, preferably a density of midscale value. This verification should be made prior to film evaluation and again after each 15 films.

(b) *Availability.* The MACBETH GN–304 densitometer is available from the Medical Stores Section, U. S. Naval Supply Depot, Mechanicsburg, Pennsylvania. Instructions for use, care, and maintenance are prescribed in the manufacturer's manual which accompanies each densitometer.

(6) *Calibration of Dosimetric Film.*—Quality control calibration curves for Type 3 film are prepared by BUMED, Code 7421, prior to supply system release of each emulsion lot. Curves or correction factors will be distributed by BUMED for sensitivity variations greater than ± 15%. Notification of variations less than ± 15% will not normally be made. Activities desiring to prepare their own calibration curves may do so, provided they submit evidence to BUMED, Code 7421, of high quality performance in calibration, processing, and evaluation of dosimetric film. Refer to Appendix B for information required by BUMED for granting permission to prepare calibration curves.

6–4. Film Processing Procedures

(1) *Frequency.*—Film shall be processed according to the following schedules.

(a) *Kodak Type 3.* Kodak Type 3 films shall be processed and read monthly within 5 days after film collection, or more frequently as deemed necessary. Under special circumstances of consistently low exposures, and with approval of the Radiation Health Officer, personnel film may be processed twice per quarter. Posted film will be evaluated at least quarterly.

(b) *Neutron Film.* Neutron film shall be processed and read whenever a high radiation exposure is suspected, or as deemed necessary by the Radiation Health Officer. However, if neutron film is issued but not normally processed, at least five percent of the issued neutron film shall be evaluated each quarter. This film shall be selected from personnel receiving the highest gamma exposures and from those with greatest access to neutron fluxes. Posted neutron film shall be processed monthly or when an incident or accident occurs.

(2) *Processing Solutions.*—All dosimetric film shall be processed with Developer, X-ray Film Processing, Rapid Speed, Powder, Kodak, dilute to 1 gallon (FSN 6525–763–4615); and Fixer, X-ray Processing Powder, Kodak, dilute to 1 gallon (FSN 6525–579–9112); or Developer, Film Processing, Kodak, dilute to 5 gallons (FSN 6525–935–4097); and Fixer, Film Processing, Kodak, dilute to 5 gallons (FSN 6525–935–4105) may be substituted, if desired. Deviation from the prescribed factors of mixture, time, and temperature will invalidate all calibration values and introduce serious error in exposure reading. Developing and fixing solutions must be made with distilled or demineralized water (according to instructions on the containers) and stirred with individual stirring rods. The temperature must be maintained at 68° F. (20° C.) with not more than ± 1° F. variation. Solutions will not be renewed by "spiking" with replenisher. Solutions should not be used continuously for more than 2 weeks, but solutions may be kept for occasional use in light free, temperature controlled conditions up to four (4) weeks. Except in emergency cases, new solutions should be allowed to stabilize 24 hours before use. Processing tanks must be thoroughly scrubbed and rinsed when solutions are renewed.

(3) *Film Packets.*—Kodak Type 3 and Type A packets should be opened in total darkness. If necessary, a safelight may be used under the following conditions: (1) when using a Kodak Safelight Wratten 6B filter, and; (2) when using a 7.5 watt frosted glass bulb. Keep the safelight not less than 4 feet from unwrapped film, and test to show that no density increase occurs when unwrapped film is exposed under these conditions for a period of 20 minutes. When dark rooms are equipped with any fluorescent lighting, these lights must be turned off at least 30 minutes before opening any film packets. This is necessary because of residual light which is often emitted from fluorescent lights after they have been extinguished. Films are placed in the film processing racks preferably by consecutive serial numbers with at least one control film packet included in each rack. All serial numbers should have been previously logged. The slow film, which lies behind the fast film, may be retained in the film packet, placed in a light tight

container, and stored for possible later development. If high densities near the upper range of the fast film are encountered which exceed the range of the densitometer, the slow film and slow control film should then be processed and evaluated.

(4) *Processing Techniques.*

(a) *Developing.* Immerse film rack in the developer and agitate for 5 seconds to dislodge air bubbles clinging to the film surface. Agitate for 10 seconds at 1 minute intervals during the required developing time to insure uniform film development. Develop Type 3 beta-gamma film for 5 minutes and Type A neutron film for 8 minutes.

(b) *Rinse.* Immerse film rack in clean water at 65° to 70° F and agitate for 10 seconds to remove developing solution from the film. Then immediately place the film rack in the fixer solution.

(c) *Fixing.* Agitate the film rack immediately upon immersion for 10 seconds. Room lights may be turned on after the films have been fixed for 10 minutes. Type 3 and neutron Type A film both require a 15-minute fixing time.

(d) *Washing.* After fixing Type 3 and neutron Type A films, they are washed in clear, clean tap water between 65° to 70° F for 30 minutes. Water flow shall be sufficient for 8 changes per hour in the volume of the wash container.

(e) *Drying.* All film shall be dried in dust-free air at temperatures not to exceed 120° F. Higher temperatures cause changes in film density. Drying time depends on air temperature and humidity, and may require 2 to 3 hours to dry and harden the emulsion in still air. Time may be shortened to as little as 30 minutes with a heated forced air dryer.

6–5. Film Interpretation Procedures

(1) *Common Faults.*—Film that is old or has been exposed to extremes of temperature or humidity will exhibit mottled, spotty, or non-uniform densities. Film thus affected should not be used and should be reported in accordance with article 6–8 of this manual. Care should also be taken not to read film on the densitometer through a flaw, fingerprint, or one of the serial numbers.

(2) *Beta, Gamma, X-ray Evaluation*

(a) *Density.* The densitometer must first be zeroed and calibrated, as directed by the manufacturer's manual. Then the density of the control film is read and an average control density determined. Each of the exposed films is then read in the areas of interest, and for each area an average density is established. These densities are then recorded for each film number. The zero setting and calibration of the densitometers should be rechecked every 15 films. NOTE: Exposed film must be read for all types of radiation from which an exposure is possible; i.e., beta, gamma, neutron, and X-rays.

(b) *Evaluation.* For gamma evaluations the average control density is subtracted from the average density under the cadmium shield. The net cadmium density is then applied to the gamma calibration curve to determine the exposure. Since the QF for gamma is one, no adjustment is necessary, and the exposure taken from the curve becomes the recorded "dose." The gamma calibration curve for Type 3 film is prepared using a moderately collimated Cobalt 60 source. In contrast to the once used radium calibration, no significant difference is noted between the density of the open window and the shielded areas of the film. Therefore, if the open window and the shielded readings are found to be similar in density, it may be assumed that the exposure was due entirely to high energy (hard) gamma. An increase in open window density generally indicates an exposure to X-ray, beta, or gamma photons below 0.2 Mev. In the case of mixed beta or mixed X-ray and gamma, the beta or X-ray exposure is obtained by the difference between the net open window and the net cadmium densities. Exposure is determined from the calibration curve for the radiation involved. Beta exposure is recorded as skin dose "soft" following the instructions of item number 9 on the back of DD Form 1141 (May 1967). Since the QF of beta or X-ray is one, no alterations are necessary to the exposure indicated by the calibration curve. In deciding between beta or X-ray, it is noted that beta exposures produce a poorly defined open window that is fuzzy in appearance. In the case of X-ray, the open window is sharply defined and the single steel and double steel are clearly distinguishable. In the case of high-energy X-ray exposure, the cadmium and cadmium plus steel are also well defined. Density ratios between the open window and the four shielded areas enable the type and the effective energy of the exposure to be determined and provide correction factors to use with a standard calibration curve for more exact exposure evaluation. Further information about density ratios may be obtained from BUMED, Code 7421, upon request.

(c) *Caution.* It should be pointed out that gamma and X radiations are identical, except for their origin in the atom, and are produced in a wide range of energies, both in the primary beam or at reduced levels as secondary radiation. It is important for greatest accuracy that the film be calibrated with a radiation source of the same approximate energy as that being monitored.

(3) *Thermal Neutron Evaluation.*—Thermal neutron exposures in the range from 2 millirem to 10 rem are evaluated using the Kodak Personnel Monitoring Film, Type 3. Cadmium, having a relatively high thermal neutron absorption cross-section in comparison to steel, emits an instantaneous gamma photon with the absorption of a thermal neutron. This photon causes an increased film density under

the cadmium, but does not affect film density under the double steel. Therefore, the thermal neutron exposure is evaluated by entering the Thermal Neutron Calibration Curve (contained in Appendix C) with the cadmium minus double-steel density. Thermal neutron exposures greater than 10 rem must be evaluated using the Accident Dosimeter attached to the film holder. The Accident Dosimeter will be provided only to activities with special requirements.

(4) *Fast Neutron Exposures.*

(a) *Fast Neutron Effect on Type A Film.* Fast neutron exposures from 30 mrem to 10 rem are evaluated using the Kodak Personnel Neutron Monitoring Film, Type A. The Type A film detects fast neutrons in an energy range from about 0.6 to 14 Mev by recoil protons producing ionization tracks in the film emulsion. A recoil proton of 0.3 Mev, resulting from the elastic collision of a 0.6 Mev neutron with a hydrogen nucleus, produces a track of 3 to 4 grains in length (3 or 4 μ). Therefore, to be counted, a track must consist of at least 3 adjacent grains.

(b) *Effect of Thermal-vs-Fast Neutrons on Type A Film.* The Type A film will detect thermal neutrons by reactions with nitrogen nuclei, $14_N(N,P)\ 14_C$. The proton that results from this reaction has an energy of about 0.6 Mev, which produces a track of 8 to 10 grains in length (6 μ). These tracks will be indistinguishable from tracks produced by recoil protons of the same energy. However, the response of the Type A film to thermal neutrons is less than for fast neutrons by an approximate factor of 20. Therefore, the Type 3 film will be used as previously described for thermal neutron exposures and all tracks on the Type A film will be considered as those resulting from a fast neutron exposure. There is virtually no response of the Type A film to neutrons between the energies of a few ev up to about 0.6 Mev.

(c) *Microscopic Procedure.*

1. Fast neutron exposures are evaluated by counting the number of tracks in a given area of the Type A film with a microscope. A binocular microscope equipped with a mechanical stage, a light field condenser, and an oil immersion lens capable of providing approximately 1000X total magnification should be used for this procedure.

2. The processed film should be placed in some suitable film holder to flatten the film and prevent slippage during reading. The film holder is placed on the microscope stage and a drop of immersion oil placed directly on the film. The oil immersion lens is lowered slowly into the oil until the film grain is in focus. Starting at one end of the film, the mechanical stage is moved along the X-axis while continually oscillating the fine focus. Tracks of three or more adjacent grains will appear to have a "fishtail" effect. This effect is a diffuse appearance tailing off the emulsion grains and is due to the darkened grains at various depths in the emulsion going in and out of focus.

3. Either discrete field counting or traverse scanning may be used. However, the total film area viewed must be known in either case. This may be accomplished by measuring the individual field size with a glass slide micrometer or a haemocytometer on which lines of definite dimensions are inscribed. Thus, knowing the area of one field, it then becomes a simple matter to compute the total area viewed.

(d) *Computing Exposures.* Control neutron film must be processed and read to establish the background occurrence of tracks. Normal control film background from cosmic rays runs 0 to 3 tracks per 50 fields (1.0 mm^2). Issued film may then be read by viewing at least 25 fields (approx. 0.5 mm). If two or less net tracks (gross tracks minus background tracks for the same area) are observed, disregard and enter the neutron exposure on DD Form 1141 as zero. If three or more net tracks are observed, proceed to read at least a total of 50 fields (approx. 1.0 mm^2). The number of tracks per unit of neutron exposure depends on the amount of film area viewed. Fifty fields is considered the minimum film area from which reliable results can be obtained. Based on this 50 field procedure, a neutron exposure of 30 millirem (3 net tracks per mm^2) is the minimum detectable dose, while 10 rem (1000 net tracks per mm^2) represents the point at which tracks are too numerous to count.

(e) *Special Considerations.*

1. New film should be procured if the expiration date has been passed, or if the background exceeds 5 tracks per 50 fields (1.0 mm^2).

2. When a high energy neutron (generally from cosmic rays) strikes the nucleus of a heavy atom present in the emulsion, an inelastic collision occurs, causing a spallation, or "thorium star." This will be seen as three or more tracks emanating from a single point and is counted as one track. When only two tracks are seen emanating from one point, they are counted as two tracks.

3. Track fading can be a problem with the Type A film. This occurs primarily with the delay in time between exposure and processing. Track fading is further increased when the film is used in areas of high humidity. This problem can be minimized by processing the film as soon as possible after a suspected or accidental exposure has occurred. There is negligible track fading once the film has been properly processed.

(f) *The Calibration Curve.* A fast Neutron Calibration Curve contained in Appendix C is furnished by BUMED (Code 7421) to evaluate exposures on the basis of net observed tracks. This curve provides for reading 25 fields (0.5 mm^2), 50 fields (1.0 mm^2), 100 fields (2.0 mm^2), and 200

fields (4.0 mm²). If total areas other than the ones provided are used, millirem per track factor can be derived by dividing the total area viewed into 10. The standard calibration curve provided by BUMED is prepared on the basis of 5.5n/cm²/sec being equivalent to one millirem per hour. This factor conservatively estimates neutron exposure for plutonium-berylium sources and for a flux of fast neutrons penetrating the secondary shield of nuclear-powered ships.

6–6. Accident Dosimeter Interpretation Procedure

(1) *Accident Dosimeter.*—The range limitations on dosimetric film have made it necessary to devise a method to detect and measure high exposures such as might be incurred in a nuclear accident. This capability has been incorporated into an accident dosimeter, which can be attached to the standard Navy film badge. These accident dosimeters are presently in the development stage. Notification will be made when they become available. Individuals who work in an area where nuclear accidents or high exposures are possible will be required to be monitored by accident dosimeters. The accident dosimeter has the capability of measuring neutron and gamma exposures from 10 Rem to 50,000 Rem and above. The accident dosimeter contains a sulfur pellet, an indium foil, and a thermoluminescent dosimeter (TLD 700 grade). The sulfur pellet will detect high energy neutrons (N:P reaction for neutrons > 3 Mev), and the bare indium foil will detect thermal neutrons (n,r reaction). Thermal neutron exposures from less than 10 Rem to the limit of the meter can be detected by the probe of the AN/PDR–27 from the radioactivity induced in indium. The accident dosimeter is under the cognizance of NAVELEX (Code 0516). The Naval Electronic Systems Command (Code 0516) is responsible for providing instructions for the use and evaluation of this dosimeter.

6–7. Estimating Exposure in Lieu of Film Badge Data

(1) *Estimates.*—Exposure estimates from defective, damaged, or improperly processed film must be considered as inconclusive for record purposes. Lost badges cause data to be lacking for certain exposure periods. In these cases, personnel exposures should be estimated from, (a) pocket dosimeter indications, (b) recorded radiation levels and exposure times, and (c) exposure of other personnel doing similar work. Only in cases where an educated estimate of radiation exposure cannot be obtained is it necessary to assign a 1.25 rem/quarter dose as discussed in article 5–1.

6–8. Film Evaluation Checks

(1) *Evaluation Check Procedure.*—Because of the many variations possible in the processing and evaluation of dosimetric film, periodic procedural checks are required. These checks shall be made by processing and reading previously exposed check films, and comparing the determined exposure to the exposure the film was known to have received. Agreement must be within ± 25% to be considered satisfactory.

(2) *Check Film.*—Check films should be obtained by exposing film to known radiation doses from sources held by the activity or its support organization. If check films cannot be obtained in this manner, they may be requested from BUMED, Code 7421.

(a) *Beta-Gamma.* Beta-gamma films may be exposed using a TS–1189/PD Dosimeter Tester or other calibrated gamma sources. The film in a film badge should be placed face down with the cadmium shield across the open top of the tester for a period long enough to produce an exposure of at least 150 mrem of gamma. The dose rate is initially determined by placing the high range detector probe of a newly calibrated AN/PDR–27 horizontally across the open top of the tester. After processing, only the middle portion of the cadmium shielded area of the film should be evaluated. The tester's Cesium source, in its position in the lead pig, will give rise to a significant fraction of low energy photons, for which the film under the cadmium shield will be more responsive. Therefore, since the film is evaluated by entering the Cobalt 60 gamma curve with the net "cadmium density," the resulting dose must be multiplied by a 0.75 correction factor.

(b) *Neutron.* Neutron film may be exposed using an AN/UDM–5 Neutron Calibrator. For this purpose, neutron film should be placed behind a beta-gamma film, in a film badge holder. The film badge is then rigged slightly above the neutron source in the calibrator, in a position approximating the electrical center of a commonly used fast neutron detector probe, such as the AN/PDR–47. Film must remain in this position long enough to receive at least 150 mrem of fast neutron radiation. Resulting check film must be processed within 10 days of exposure to minimize track fading. As an additional exercise, the accompanying beta-gamma film should be evaluated for density due to thermal neutrons.

(3) *Required Frequency of Checks.*—A minimum of two beta-gamma check films and, if normally used, one neutron check film shall be processed and read each month. Additionally, prior to issue of film from a newly acquired lot, each activity should expose and evaluate at least two representative films as described above as a check of film sensitivity and possible defects. In all cases where possible, processing personnel should not know the identity of the check film, the dose it received, or the fact that a check is being made.

(4) *Additional Checks.*—Prior to processing film, checks of related chemicals and equipment should be made. Such checks should include the following items:

(a) *Thermometer.* The darkroom thermometer should be compared with several other thermometers so as to demonstrate a probable accuracy of ± 1 in the 68° F. range.

(b) *Solutions.* Processing solutions shall be prepared with distilled or demineralized water, and must be within proper age and temperature parameters. Solutions must be clear and free of foreign material.

(c) *Densitometers.* Densitometers must be checked prior to use for proper operation, including "zero set" and density calibration.

(5) *Required Records and Reports.*—Each use of check film will be recorded including the film exposure, the estimated dose and the percent error, if errors greater than ± 25% are noted. The circumstances producing the error must be investigated, corrected, and recorded by the Radiation Health Officer or designated local authority. If such errors cannot be explained and corrected locally, a letter report, Film Exposure vs Film Interpretation Error Report MED 6470–6, giving full details must be submitted promptly to BUMED, Code 74. Similarly, a Film Interpretation vs Pocket Dosimeter Reading Error Report MED 6470–7, detailing differences greater than 25% between exposures over 150 mrem determined by film badge and by pocket dosimeter must be reported to BUMED, Code 74, if they cannot be explained and corrected by the activity involved. In all cases, such differences must be recorded.

(6) *Photodosimetry Audits.*—To ensure that the regulations, procedures, and checks specified herein are appropriately complied with, semi-annual photodosimetry audits will be conducted. For forces afloat, these audits shall be made by Squadron Medical Officers, their equivalents, or their designated representatives. Shore based activities should conduct their own audits by utilizing personnel as inspectors who are knowledgeable in the Radiation Health field, but who are as independent as possible of the local photodosimetry program. Additional audits may be held as directed by District Medical Officers or by BUMED, Code 74. Discrepancies noted on photodosimetry audits shall be reported to BUMED, Code 74, by Photodosimetry Audit Discrepancy Report MED 6470–8.

(7) *Reporting of Other Photodosimetry Discrepancies.*—In field or fleet activities, discrepancies in photodosimetry results sometimes occur due to defective film, defective processing chemicals, or other technical fault. If an occurrence of this nature should arise, a report of the discrepancy shall be made by letter to BUMED, Code 7421.

INFORMATION REQUIRED BY BUMED FOR PERMISSION TO PREPARE CALIBRATION CURVES

A. Statement of justification.

B. Type or types of calibration curves to be prepared.

C. Exposure range to be covered.

D. Describe film holder to be used, include filter materials and thicknesses.

E. List sources available and description of each:

1. Gamma—Bureau of Standards calibration certificate and/or Bureau of Standards calibrated instruments used for measurement of output.

2. Beta—If natural uranium plaque or uranium oxide ore is used, state output and conditions of exposure; i.e., if film is exposed bare or in the film holder. If other beta sources are used, state method of determining output.

3. X-ray—List KVP, added filtration, determined HVL, and KEV effective. Include Bureau of Standards calibrated instruments used for measurement of output.

4. Neutron—Source certification by Bureau of Standards and/or manufacturer. Include all calculations and conversion factors.

NOTE: If thermal neutron calibrations are attempted, describe the method in detail.

F. Describe calibration equipment:

1. Submit sketch of equipment setup; to include, source to film distance and distances between equipment, deck, and bulkheads.

NOTE: If fixed time and varying distances is the method of choice, list each distance.

G. Describe processing unit:

1. Make and model of processing tank including temperature maintaining capability.

2. Type developer and fixer used, and frequency of renewal.

3. List processing times for developing, rinsing, fixing, and washing.

H. Evaluation methods:

1. Density measurements—Make and model of densitometer. Year of make and date of last maintenance. Availability of calibration wedge. Frequency of densitometer calibration.

2. Microscope technique—Make and model microscope. Magnification and type of condenser used. Include viewing method; i.e., direct, projection, television, etc. State the area of one field of view. In addition, list the number of fields and/or the total film area viewed.

I. Submit samples of calibration curves.

APPENDIX C—CALIBRATION CURVES

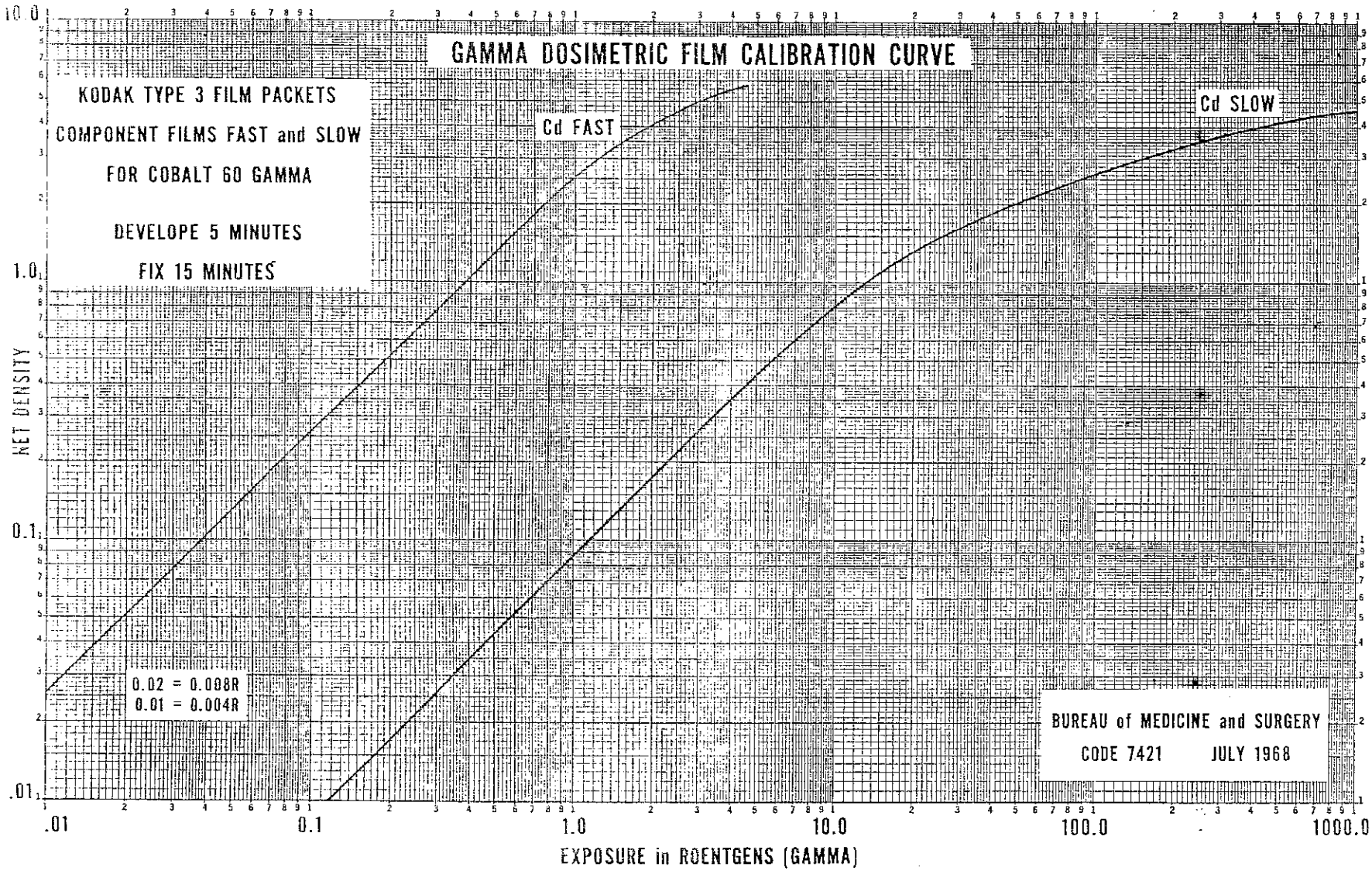
DOSIMETRIC FILM CALIBRATION CURVE, GAMMA

DOSIMETRIC FILM CALIBRATION CURVE, X-RAY

DOSIMETRIC FILM CALIBRATION CURVE, BETA

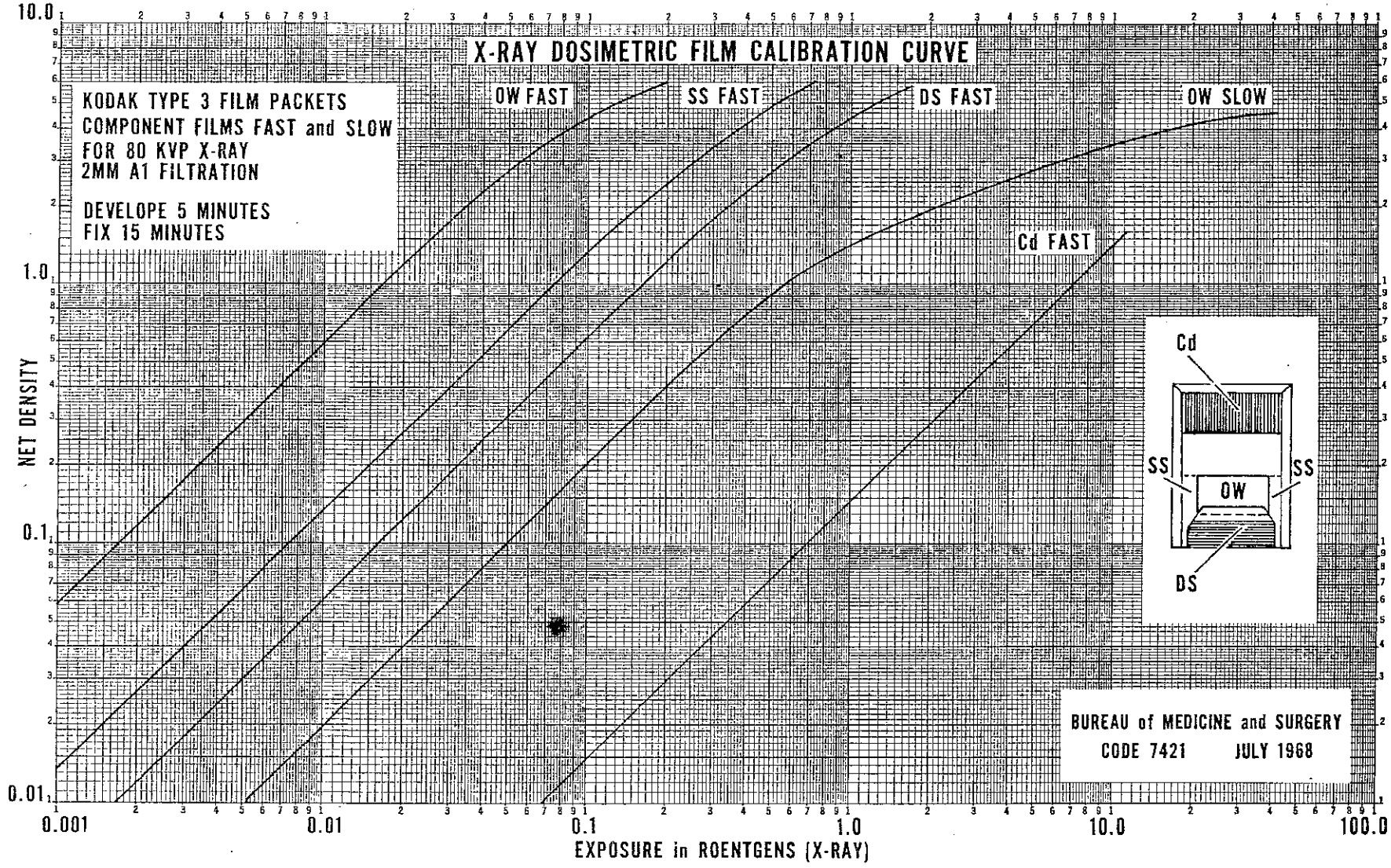
DOSIMETRIC FILM CALIBRATION CURVE, THERMAL NEUTRONS

DOSIMETRIC FILM CALIBRATION CURVE, FAST NEUTRONS



OCTOBER 1968

C-2



C-3

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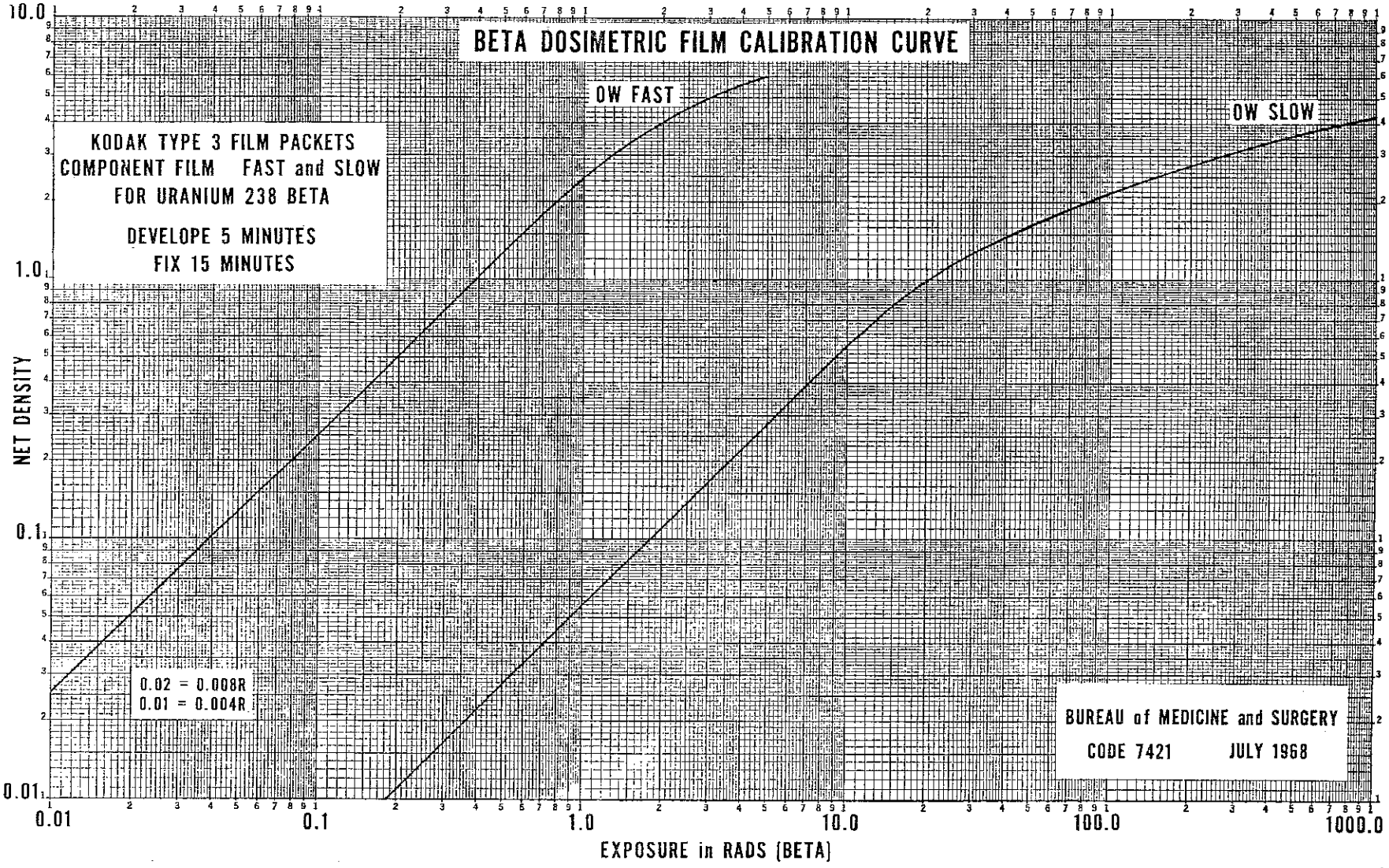
BETA DOSIMETRIC FILM CALIBRATION CURVE
OW FAST
OW SLOW
KODAK TYPE 3 FILM PACKETS
COMPONENT FILM FAST and SLOW
FOR URANIUM 238 BETA
DEVELOPE 5 MINUTES
FIX 15 MINUTES
0.02 = 0.008R
0.01 = 0.004R
BUREAU of MEDICINE and SURGERY
CODE 7421 JULY 1968
NET DENSITY
10.0
1.0
0.1
0.01
0.01
0.1
1.0
10.0
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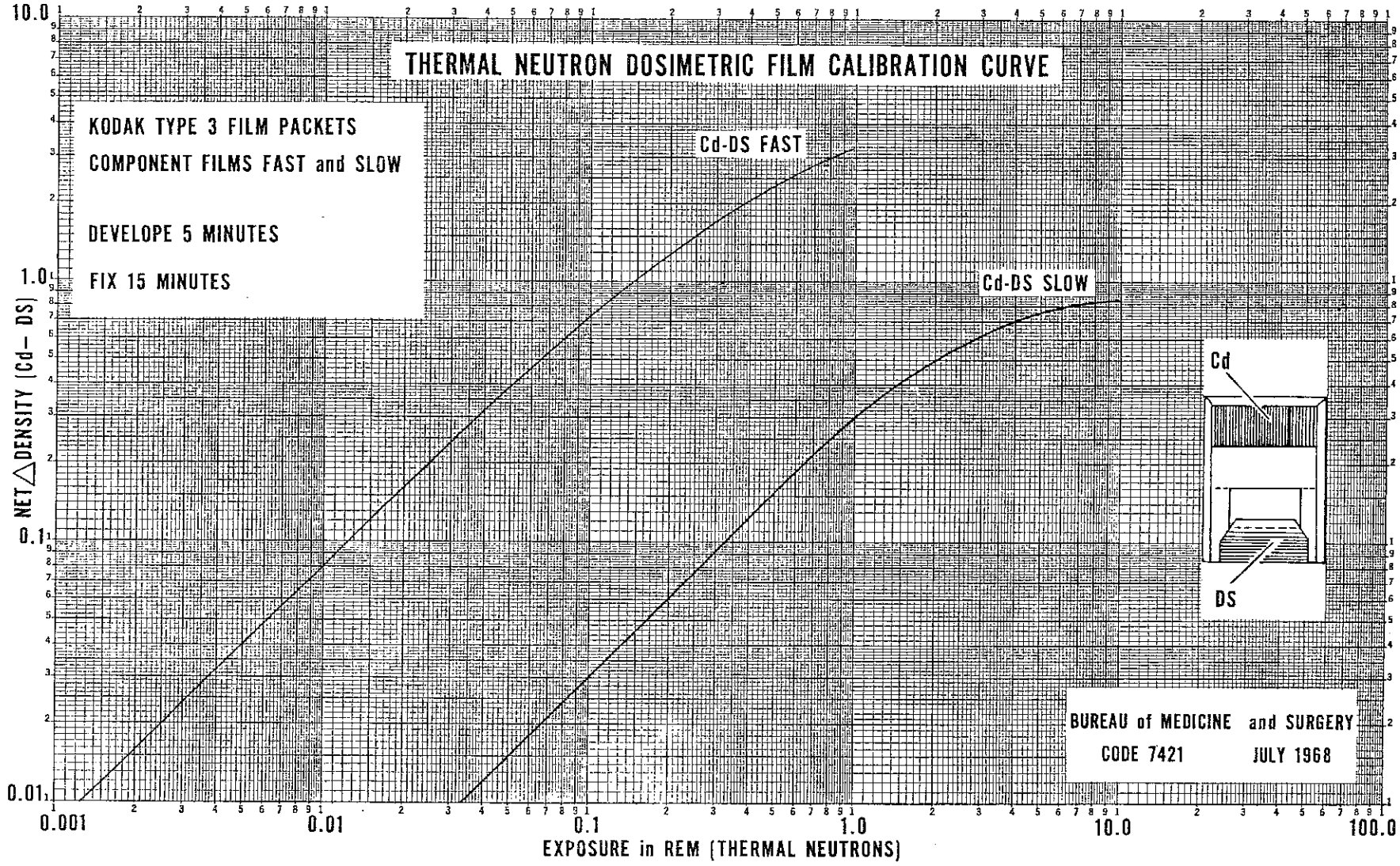
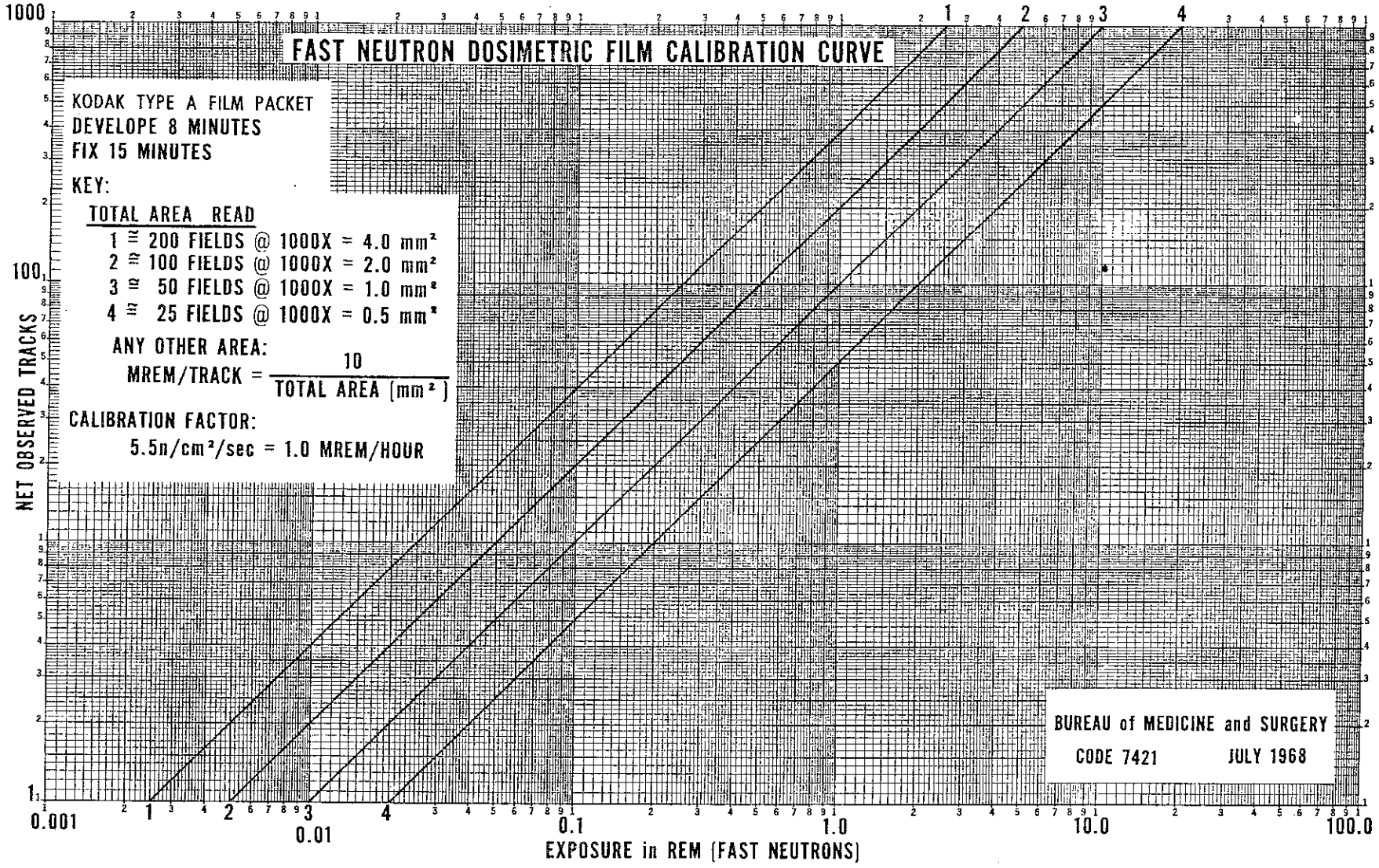
1000.0
EXPOSURE in RADS (BETA)


THERMAL NEUTRON DOSIMETRIC FILM CALIBRATION CURVE
KODAK TYPE 3 FILM PACKETS
COMPONENT FILMS FAST and SLOW
DEVELOPE 5 MINUTES
FIX 15 MINUTES
Cd-DS FAST
Cd-DS SLOW
Cd
DS
BUREAU of MEDICINE and SURGERY
CODE 7421 JULY 1968
NET △DENSITY (Cd– DS)
10.0
1.0
0.1
0.01
0.001
0.01
0.1
1.0
10.0
100.0
EXPOSURE in REM (THERMAL NEUTRONS)



OCTOBER 1968